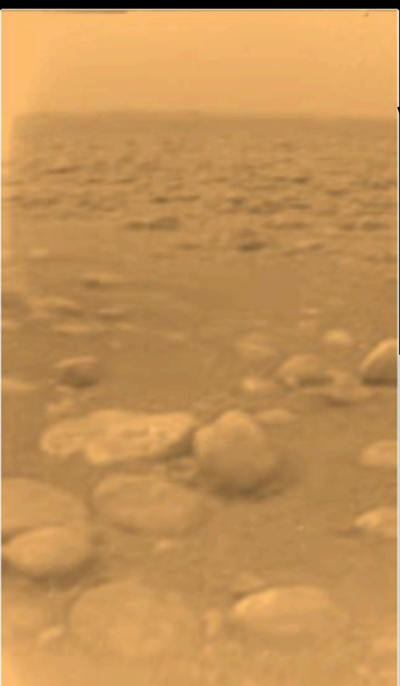
Mission Concepts for Titan Exploration



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PRE DECISIONAL
For Planning and Discussion Purposes Only

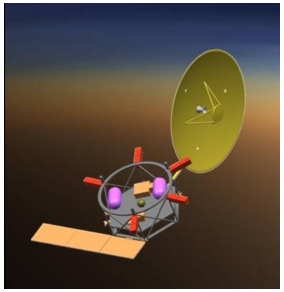
Topics

- Platform options for addressing Titan science
- Mission options
- Titan mission studies (and proposals) since Cassini/Huygens' arrival

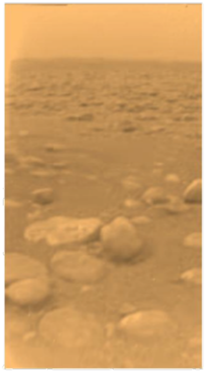
Platform Options

Useful Platform Options

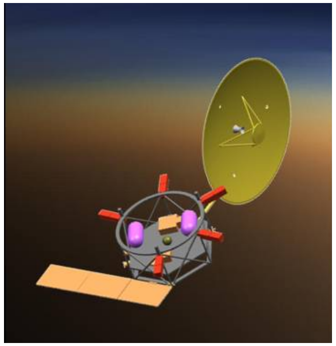
- First: platforms that are not particularly useful
  - Flyby spacecraft: Cassini has already done most of that
  - Surface rovers: not enough range to sample Titan's diversity
    - Example exception: precision-landed rover near a cryovolcano vent
- Orbiters
- Entry Probes
- Aircraft



  - Lighter than air: balloons (superpressure, hot-air, wind-driven, engine-driven), blimps, dirigibles
  - Heavier than air: drop sondes, gliders, airplanes, rotorcraft
- Landers
- Sea-craft
  - Buoys, boats (wind-driven, engine-driven)
  - Submarines



Orbiters



- Environments they can observe directly:
  - Saturn magnetosphere, Titan ionosphere
    - Fields & particles investigations
  - Titan exosphere & upper neutral atmosphere (eccentric orbit)
    - Composition: in situ (mass spec), remote sensing (UV occultations)
- Global mapping & topography of surface
  - morphology, geology, limited composition
  - IR mapping spectrometry, hi-resolution SAR, altimetry
- Radio science investigations
  - Gravity field: interior structure, gross geology (limited by altitude)
  - Occultations: atmospheric and ionospheric structure, inferred winds
- Useful data relay node for aerobots, landers, etc.
- Challenges
  - Orbit insertion: requires aerocapture, which needs a flight demo
  - Needs a significant RPS
    - Fuel requirements are within anticipated availability

Entry Probes

- Environments they can observe directly:
  - "Agnostosphere" (or "ignorosphere")
    - Composition, atmospheric structure
  - Stratosphere, troposphere
    - Composition, atmospheric structure & dynamics (winds)
    - Local haze layers and clouds, insolation
  - Surface
    - Descending below ~20-25 km, imaging resolution improves but coverage decreases (parafoil improves coverage)
    - Limited composition
- Challenges
  - Single probe does not sample Titan's diversity
  - Brief science mission; "snapshot"

Aircraft - 1

For the first Titan aerobot mission:

Heavier than air ...

- *or* -

Lighter than air ?

- Stability & “safe mode”: what happens if computer crashes?
  - Superpressure balloon: nothing; stable, stays put at design altitude
  - Hot-air balloon: stable; simple hardware controller can initiate ascent to safe altitude
  - Blimp/dirigible: stable; simple hardware controller can initiate ascent to safe altitude, but slower and lower than hot-air balloon
  - Airplane: marginally stable; neutralizing control inputs yields a stable configuration, but can lose much altitude before flight stability regained
  - Glider (parafoil?): similar to airplane, but short mission duration
  - Helicopter: unstable without active control inputs; crashes within a few seconds to a few minutes of computer loss

Looks like lighter than air wins out

Aircraft - 2

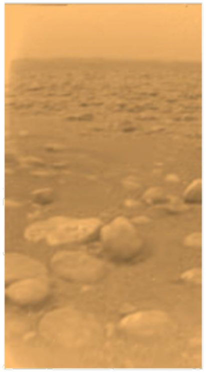
- Comparison of lighter-than-air craft

Characteristic	Superpressure Balloon	Hot-air Balloon	Blimp/ Dirigible
Simplicity	Simplest	Simple	More Complex
Expected Lifetime	Year?	Many Years	Year?
Vertical Range	~ None	Near-Surface to 10-12 km	Near-Surface to ~2 km
Surface Sampling Capability	No	Yes	Yes
Hover Capability	No	No	Yes

Aircraft - 3

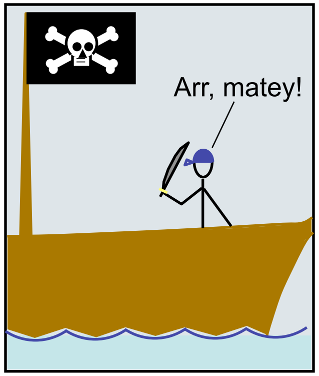
- Environments hot-air balloons or blimps can sample directly, over a wide variety of locales:
  - Lower troposphere
    - Composition, atmospheric structure & dynamics (winds, circulation)
    - Local clouds, insolation, meteorology
    - Surface-atmosphere interaction
    - Temporal variability (including seasonal for duration ≥~2-3 years)
  - Surface
    - Detailed composition of marginally- to precisely-targeted areas (mass spec w/sampler)
    - Local high-resolution imaging: morphology, topography, gross composition & distribution
  - Subsurface
    - Layering and structure (subsurface radar): geology, geologic history, buried structures (such as impact craters)
    - Lake-bottom topography, sedimentation styles
- Challenges
  - Autonomous control algorithms; low-T operations; deployment?

Landers



- Environments they can observe directly:
  - Near-surface troposphere
    - Meteorology: temperatures, pressures, humidities, local winds, clouds, precipitation
  - Surface
    - Detailed composition, texture of surface & shallow subsurface materials
  - Subsurface
    - Drilling: local layering of shallow subsurface; heat flow?
    - Local ground-penetrating radar or active seismic
  - Interior
    - Seismic activity, interior structure (requires multiple simultaneous landers & natural seismic activity)
- Challenges
  - Limited area sampled; one lander does not sample Titan's diversity
  - Low-temperature operations
  - Precision landing?

Sea-craft



- Environments they can observe directly:
  - Near-surface troposphere
    - Meteorology: temperatures, pressures, humidities, local winds, clouds, precipitation
  - Liquid
    - Detailed composition, depth sounding
    - Wave heights, wavelengths, directions
    - Temperatures, temperature gradients, thermoclines
    - Evaporative loss rates
  - Subsurface
    - Sub-bottom active seismic?
- Challenges
  - Thermal (staying warm)
  - Communications, if no orbiting relay

Mission Options

Mission Options for Titan Exploration

- A “mix-and-match” of elements
  - Different platforms treat different objectives
    - *Some*, but not *excessive*, overlap
    - Much complementarity, significant synergy
    - Can easily justify combining different platforms, or multiples of one type
  - A few caveats
    - Beware of “Just add a (favorite platform)”; costs can spiral
    - Huge synergy with an orbiter: multiply data volume from in situ platforms by a factor of 50 to 100 compared with direct-to-Earth downlink
    - Aerocapturing into Titan orbit (or at Titan into Saturn orbit) might require that *your mission foot the bill* for an aerocapture flight demonstration
- Getting to the Saturn system
  - Many ballistic or low-delta-V trajectories to Saturn using inner solar system gravity assists -- cruise durations 7-10 years
    - Some flexibility in choosing arrival parameters
  - Solar Electric Propulsion can increase mass capability and/or shorten cruise durations, but adds (currently) ~$100M to mission cost

Low-Cost Titan Mission Options

"Billion-Dollar Box" Study Conclusions

Science Value, Cost and Risk assessments were synthesized to form the basis for conclusions regarding feasibility:

- No missions to Titan or Enceladus that achieve a sufficient increase in understanding beyond Cassini-Huygens, were found to fit within the cost cap of 1 billion dollars (FY'06)

- Three of the missions studied have the potential to meet the cost cap but fall below the science guideline established for this study
  - Single Fly-By of Enceladus
  - Single Fly-By of Titan
  - Single Fly-By of Titan with Atmospheric entry Probe (Huygens-like)

- Even the lowest-cost mission option, **without the science payload cost**, has a minimum expected cost of ~$800M, making it highly unlikely that unexplored approaches exist that achieve sufficient science value for $1B

- All Titan and Enceladus missions that meet science guidelines require new technology development or flight validation

Titan Mission Studies Since C/H Arrival

- NASA "Vision Missions" study, J.I. Lunine (U Ariz) PI, JPL
  - Significant engineering study of surface sampling systems
- Univ. of Arizona/JPL study, "Titan Protobiological Explorer" (TiPEx)
  - Refinement of science objectives, payload priorities
  - Engineering studies of multi-element telecom, Montgolfiere design
- NASA/JPL "Billion Dollar Box" study
  - Ralph Lorenz (now of APL) lead of SDT
- NASA/APL/JPL Titan Flagship Mission study
  - Three science elements: orbiter, lander, aerobot
- European Cosmic Visions Program proposal, "TANDEM"
  - Led by Athena Coustenis (Obs. de Paris, Meudon)
  - Investigations at both Titan and Enceladus
  - Delivers a balloon to Titan

Any Questions?